Aspects of breeding ecology of the Brown Goshawk (*Accipiter fasciatus*) in an urban environment in northern Australia

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Abstract

The breeding parameters of the Brown Goshawk (*Accipiter fasciatus*) have yet to be documented in an urban environment in Australia. Twenty-six active nests were located in urban Darwin during the 2013–2014 breeding season. Incubation occurred from August to November over a 12 week laying period. Twenty-two nests were in introduced African Mahogany trees (*Khaya senegalensis*) and four were in River Red Gums (*Eucalyptus camaldulensis*). One or more young matured to fledgling stage or later at 17 of the 26 nests, with an average fledging rate of 1.13 young per nest. Assuming that all active nests were detected, the breeding density of Brown Goshawks across the study area is 52 nests per 100 km^2, which is higher than that recorded in previous studies on the species.

Introduction

The Brown Goshawk (*Accipiter fasciatus*) occurs throughout mainland Australia and on the surrounding islands, including Wallacea, New Guinea, New Caledonia and the Solomon Islands (Debus 2012). The species occurs in wooded and forested lands of tropical and temperate Australia. Abundance is highest in woodland or open forest but a variety of habitats are used, with individuals occurring wherever trees or tall shrubs provide cover for ambushing prey (Marchant & Higgins 1993). Incubation lasts 29–31 days with fledging occurring at 28–37 days (Olsen *et al.* 1982).

The breeding parameters of the Brown Goshawk have previously been described in southern Victoria (Aumann 1989) and north-eastern Queensland (Burton *et al.* 1994). These studies were undertaken in areas partially disturbed by agriculture (Aumann 1989) and forestry (Burton *et al.* 1994). There have been no previous quantitative studies on the breeding parameters of this bird in an urban environment. Ecological aspects of urban-breeding *Accipiter* hawks have previously been described for Northern Goshawk (*Accipiter gentilis*) and Eurasian Sparrowhawk (*A. nisus*) in Europe (Papp 2011; Rutz 2006), and Cooper's Hawk (*A. cooperi*) in North America (Haimann 2006; Ward & Mannan 2006). This paper details aspects of the breeding ecology of Brown Goshawk in an urban environment in northern Australia

and includes observations on breeding density, reproductive success, nesting habitat and prey.

Study area

Field work was conducted from August 2013 to February 2014 in a 49.77 km^2 (4977 ha) area within the city of Darwin (city centre co-ordinates 12.461°S, 130.841°E). The study area consisted of most residential suburbs within the city of Darwin, extending from The Gardens and Stuart Park in the south to the northern suburbs of Tiwi and Wanguri, bordered by Karama to the northwest. Large reserves fringing the urban environment, such as East Point and Holmes Jungle, were not surveyed. Industrial suburbs with very little tree cover, such as Winnellie and Berrimah, were excluded, as was the rural suburb of Knuckey Lagoon. Areas with restricted access, such as large private properties and Defence land, were also excluded.

Darwin experiences a tropical savanna climate with distinct wet and dry seasons. The wet season, between October and April, brings significant monsoonal rains and occasionally cyclones. In contrast, negligible rainfall occurs during the dry season (May to September).

The urban Darwin environment is characterised by houses with well-watered landscaped gardens interspersed with numerous council parks, schools and sports ovals fringed by large trees. These large trees include the exotic African Mahogany (*Khaya senegalensis*), planted throughout the city following Cyclone Tracy in 1974, and several planted species of eucalypts not necessarily native to the area.

Methodology

Nests of Brown Goshawk were located by undertaking systematic ground surveys throughout the study area. All council parks and school ovals fringed by large trees, particularly African Mahogany, were surveyed. The parks were located with the aid of a street directory while Google Earth helped locate additional clusters of large trees. The author used knowledge accumulated in previous years, including five nesting locations as well as areas where Brown Goshawks had been observed roosting and undertaking territorial displays. A request for Brown Goshawk information was posted on a local birding internet forum, and further information provided by local naturalists also aided the detection of nests.

Active Brown Goshawk nests were monitored every 2–4 weeks. The timing and duration of the breeding cycle was determined from observations and photographs made near the nest. Photography of adult Brown Goshawks helped to determine sex and identify individuals through variations in size and plumage (Figure 1). Photographs of juvenile birds helped to estimate their age and to establish timing of breeding events. Previous analysis of Brown Goshawk nestling development by Olsen *et al.* (1982) was referred to in order to estimate the age of nestlings.

Locations of active nests were recorded on a Global Positioning System (GPS) device. Active nests were mapped to assess their distribution and breeding density. Breeding success was expressed as the number of young fledged per active nest for those nests where the breeding outcome was known. For nests where the number of fledged young was uncertain, success was defined to be at least one youngster fledged.

The distances between nests were calculated by mapping active nests within the project area onto Google Earth and using the ruler function to measure the distance to the nearest known nest.

Prey items were recorded by observing adults clutching or eating prey, or from prey transfers from adults to juveniles (Figure 2), or juveniles eating prey (Figure 3), or prey remains observed close to the nesting tree.

Figure 1. Variation in size and plumage between adult Brown Goshawk female (left) and male (right). (Will Riddell) ▲

Figure 2. Brown Goshawk juvenile (left) and adult (right) feeding on a Northern Water Dragon. (Will Riddell) ►

Figure 3. Juvenile Brown Goshawk feeding on a nestling of Torresian Imperial Pigeon. (Will Riddell) ►


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Results

Sample size

Twenty-six active Brown Goshawk nests in 23 territories were recorded during the 2013–14 breeding season in Darwin. There were three instances of breeding attempts in two separate nests within the same territory. Three additional non-breeding territories were identified, making a total of 26 Brown Goshawk territories identified across Darwin. The majority of Brown Goshawk nests are thought to have been located within the study area, as tall trees potentially used for nesting were sparsely distributed and could be easily identified and surveyed. A small number of nests were probably overlooked.

Timing of breeding

The majority of incubation periods began in September (eight nests) and October (eight nests), though incubation commenced as early as late August and as late as mid-November. The first recorded incubation started on 27 August 2013 while the latest confirmed start to incubation occurred on 16 November, representing a laying period of approximately 12 weeks (82 days). From the 20 nests for which timing of hatching could be estimated nestlings hatched in November at nine nests, six in October, three in December and two in September.

Nest trees

Twenty-two of the 26 active nests were located in African Mahogany trees, with four nests occurring in River Red Gums.

Breeding success

One or more young fledged successfully from 17 of the 26 active nests, giving a success rate of 65%. The outcome was known for 23 nests (Table 1). The productivity of three nests was unknown but at least one young was known to have fledged from these nests.

Breeding density

An accurate estimation of breeding density of Brown Goshawks in the urban Darwin area is not possible as some active nests were probably overlooked. Assuming that all active nests were detected, the density of active Brown Goshawk nests across the study area would be 52 nests per 100 km^2.

Mean nearest neighbour distances for active Brown Goshawk nests in Darwin were 746 ± 324 m, with a minimum of 234 m and maximum of 1420 m.

Two nesting attempts by the same pair occurred within three territories, but double brooding (two successful breeding attempts in a season) (Riddell 2011b) occurred

within only one territory. The distance between nests in this territory was 317 m. These nests were considered to belong to the same territory, and likely to the same pair, due to the timing of breeding attempts, with incubation occurring at the second nest within three days of the juvenile fledging from the first nest. Additionally, an adult male was observed undertaking a prey transfer to the juvenile of the first nest before flying toward the second nest, where it roosted.

Prey

A total of 38 prey items was recorded at 14 different territories, consisting of 20 birds, 14 reptiles and four mammals. The most commonly recorded prey item was the Northern Water Dragon (*Lophognathus temporalis*), which was recorded on eight occasions. Other prey items identified to species level included Torresian Imperial Pigeon (*Ducula spilorrhoa*) (n=2), Bar-shouldered Dove (*Geopelia humeralis*), Magpie-lark (*Grallina cyanoleuca*), Red-collared Lorikeet (*Trichoglossus rubritorquis*) (n=2), Black Rat (*Rattus rattus*) (n=2) and House Mouse (*Mus musculus*) (n=2). The remains of a juvenile friarbird (*Philemon* sp.) were also observed below a nest.

Table 1. Breeding success of Brown Goshawk in Darwin 2013–14 based on observations of 26 nests.

Result of breeding attempt	Number of records
Failed nests	9
One juvenile fledged	5
Two juveniles fledged	6
Three young fledged	3
Success but productivity unknown	3
Fledged juvenile /successful nest[1]	1.86
Fledged juvenile /active nest	1.13

[1] Excludes nests where productivity unknown

Discussion

Timing of breeding

The breeding period for the Brown Goshawk in Darwin occurs from August to January, extending from the late dry season through to the start of the monsoonal wet season. During this study incubation began between August and October for the majority (21 of 26) of nests, with juveniles fledging from October to December. This part of the early wet season is referred to as the 'build up' in tropical northern Australia, a period when temperature and humidity are high and rainfall infrequent. Following three to four months of very little rainfall, the first rains of the 'build up' initiate a chain of natural events that lead to an increase in numbers of Brown Goshawk prey species. The first seasonal flush of vegetation leads to increased activity and abundance of insects, which in turn stimulate increases in activity and breeding by lizards and passerine birds (Immelmann 1982 cited in Burton *et al.* 1994). Conditions during the 'build up' may be ideal for breeding as rainfall during this period is usually sufficient to trigger increased prey availability, yet not frequent enough to pose a hazard to nesting birds or to inhibit hunting activity.

Incubation began in November at five nests with young fledging in January. January is historically the wettest month in Darwin (BoM 2014), coinciding with frequent heavy monsoonal rain. Undertaking breeding at this time is risky as heavy rains can negatively impact breeding success (Olsen 1995). Three of the five nests where incubation began in November represented the second breeding attempt undertaken within a single territory, probably by the same pair of adults. Two of these breeding attempts occurred after the first attempt was unsuccessful, and both these attempts were also unsuccessful the second time. *Accipiter* hawks are able to raise young from a replacement clutch if their first fails at an early stage, due to their relatively short breeding cycle (Newton 1979). Grey Goshawks (*Accipiter novaehollandiae*) have been observed successfully breeding from a replacement clutch in Darwin (Riddell 2011a).

The 12 week laying period is greater than the eight to ten week period previously recorded by Aumann (1989) in Victoria and the four week period recorded by Burton *et al.* (1994) in northern Queensland. Aumann (1989) has suggested that longer laying periods occur when seasonal changes in photoperiod, weather, and/or prey availability are less pronounced. Darwin is closer to the equator than most of the Australian mainland and seasonal variations in photoperiod are relatively low. Seasonal fluctuations in temperature are also relatively small in northern Australia, but rainfall is highly seasonal and it probably influences the length of the egg-laying period. The heavy monsoonal rains of January and February may determine the latest laying dates due to the increased risk to incubation during this period. While some pairs successfully fledge young in January there is risk associated with raising young during periods of frequent heavy rainfall, such as potential flooding of the nest (Burton *et al.* 1994; Olsen 1995).

Nest trees

Twenty-two of the 26 active nests were found in African Mahogany trees. The large size, shade and multiple branching of the African Mahogany are ideal for raptor breeding, with this species also being used for nesting by Brahminy Kites (*Haliastur indus*) and Grey Goshawks in suburban Darwin (Riddell 2013a). African Mahogany trees are common throughout the urban Darwin area and are often the tallest trees within an occupied territory, making them an ideal choice of nest tree for Brown Goshawk.

River Red Gum trees were used for nesting on four occasions. One attempt at nesting in a River Red Gum failed as the nesting branch fell from the tree. The author discovered this branch lying on a walking path, but with the nest in perfect condition and a chick covered in white down sitting in the nest. Both parents were calling in the nest tree. The chick was taken to a wildlife carer.

Breeding success

The breeding success rate of 65% (i.e. 17 out of 26 successful nests) is lower than the 83% recorded in Macclesfield, Victoria (Aumann 1989) and is similar to the 63% success rate recorded at Abergowrie, Queensland (Burton *et al.* 1994). The number of fledged young per successful nest (1.86) was similar to the result recorded across three breeding seasons in Abergowrie (1.6) (Burton *et al.* 1994).

The similarity of results to those recorded by Burton *et al.* (1994) in Queensland may reflect the similarity of climate in the respective study areas; both experience a tropical climate with distinct wet and dry seasons.

A wide range of variables may influence breeding success of raptor populations in both the short and the long term (Paviour 2013). Determining specific causes of nest failure is therefore difficult. The cause of breeding failure was positively identified for only one out of nine failed attempts; a fallen eucalypt branch containing an intact nest and a chick less than five days old was discovered beneath the nest tree (see above). Four nests were observed to have chicks that failed to fledge, while no chicks were observed at four nests that had been incubated.

Failures of goshawk nesting attempts have been attributed to frequent heavy rainfall (Kostrzewa & Kostrzewa 1990; Penteriani 1997). Burton *et al.* (1994) attributed Brown Goshawk and Grey Goshawk nest failures in Abergowrie to high precipitation caused by tropical storms. Rainfall reduces hunting efficiency by impairing flight and changing prey behaviour, thus restricting the supply of food from adults to their young (Newton 1979). Rain can also cause nests to become flooded, killing eggs and young nestlings (Olsen 1995). Some nest failures in this study were likely related to frequent heavy rainfall events. Darwin experienced above average rainfall during the October to February 2013–14 wet season, including a 24-hour record of 104 mm falling at the Botanical Gardens on 4 November 2013 (BoM 2014).

Predation by other raptor species is a possible cause of nest failure. Brahminy Kites have been observed unsuccessfully attempting to prey upon Brown Goshawk nestlings in the urban Darwin area (Riddell 2013a). A Grey Goshawk was observed swooping on Brown Goshawk chicks at one nest, with the attack successfully repelled by the adult female, while Grey Goshawks were detected in the immediate vicinity of two other active nests.

Breeding density

The figure of 52 nests per 100 km^2 recorded in this study is higher than 20.3–31.3 active nests per 100 km^2 recorded at Macclesfield (Aumann 1989) and 2.2 pairs per 100 km^2 recorded near Mildura (Baker-Gabb 1983).

The mean inter-nest distance of 746 m is lower than the 1332 m recorded at Abergowie, Queensland (Burton *et al.* 1994). The minimum inter-nest distance of 234 m is significantly lower than the 1600 m minimum and 870 m minimum distances recorded at Macclesfield, Victoria (Aumann 1989) and in Abergowie, Queensland (Burton *et al.* 1994), respectively. Brown Goshawk nests have previously been found as close as 250 m in the Seaview Range, Queensland (Burton *et al.* 1994). Double-brooding by a single pair has previously been recorded in urban Darwin (Riddell 2011b) and a second instance, with an inter-nest distance of 317 m, was recorded during this study.

Discovery of two active nests 234 m apart was initially believed to be a further instance of double-brooding by a single pair, based on the timing of breeding events, with incubation in the second nest beginning immediately after two juveniles had fledged from the nearby nest. Both nests were located within a continuous stand of African Mahogany trees. Double-brooding by a single pair was disproved following a prey exchange observed between adults close to the incubating nest at the same time as a lighter-plumaged female was observed close to the nest with two fledglings. A single male may have been breeding with two females within the territory; photographs of an adult male at both nests reveal similar-looking plumage.

Prey

The proportions of birds (53%), reptiles (37%) and mammals (10%) recorded as prey items support previous descriptions of the Brown Goshawk as a generalist predator (Aumann 1988; Baker-Gabb 1983). Northern Water Dragons (*Lophognathus temporalis*) were recorded on eight occasions, and was the most commonly observed prey. These lizards are reported to be of greater size and abundance in the Darwin area than their bush counterparts due to the greater year-round water availability in the urban environment (Iglesias *et al.* 2012). The success of Northern Water Dragon in urban Darwin probably supplies Brown Goshawks with a reliable prey source throughout the year.

Of the 20 birds recorded as prey, six were nestling birds, suggesting a tendency of goshawks to exploit the increased abundance of passerine birds during their breeding seasons.

Urban effects

The Brown Goshawk can be considered a habitat generalist as it is able to occupy a variety of habitats, wherever trees or tall shrubs provide cover for ambushing prey (Marchant & Higgins 1993). Urbanisation of an environment tends to favour increased densities of generalist species (Devictor *et al.* 2008; Isaac *et al.* 2013) as they are able to exploit the heterogeneity created. Generalists that use a greater variety of habitats are also less affected by habitat fragmentation than specialist species. Generalists benefit from landscape degradation as this reduces competition with specialist species (Marvier *et al.* 2004). Brown Goshawk abundance may have increased following urbanisation of the Darwin area due, in part, to decreasing competition with the ecologically complementary but more specialised Grey Goshawk, which tends to inhabit more closed habitat and is less inclined to use ecotones than Brown Goshawk (Burton & Olsen 2000). Grey Goshawks nest in urban areas and the urban fringe around Darwin at lower densities than Brown Goshawks (Riddell 2013b).

The breeding density recorded in this study is higher than that recorded in previous quantitative studies on Brown Goshawks (Aumann 1989; Burton *et al.* 1994). Those studies were conducted in landscapes partially disturbed by agriculture and forestry and in habitats that were likely less heterogeneous than those provided by an urban environment. It is possible that urbanisation of the Darwin area may have created ecological conditions that facilitate the increased breeding density of the Brown Goshawk. Urban areas provide many different natural and artificial niches that can benefit certain species (Jones 2013). Burrowing Owls (*Athene cunicularia*) and Eastern Screech Owls (*Megascops asio*) have attained greater breeding success, in terms of chick survival and fledgling output, in urban areas than their counterparts in natural areas, due to enhanced prey availability and climatic stability (Botelho & Arrowood 1996; Gehlbach 1996). The most important ecological factor benefiting an apex predator such as Brown Goshawk may be increased prey abundance. The constant water supply of irrigated parks and gardens and protection from bushfires afforded by the urban environment probably facilitate increased densities of the lizards and passerine birds comprising Brown Goshawk prey. However, it is impossible to state definitively that urbanisation has led to an increase in Brown Goshawk density because pre-urbanisation data are lacking.

Acknowledgements

David Van den Hoek kindly identified the eucalypt for me. My thanks go to Peter Kyne and an anonymous referee for providing comments on a draft.

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